PRELIMINARY RESEARCH ON UNIVERSAL DESIGN FOR LEARNING (UDL) IN GRADES 3-6 SCIENCE EDUCATION

ABSTRACT: The Concord Consortium is developing software for elementary school science based on principles of Universal Design for Learning (UDL). The goal is to help teachers meet each student's needs, including students with learning disabilities, English language learners, and others. The UDL software we have developed includes a variety of features to make the curriculum more accessible, including: Smart Graphs and Smart Models, text-to-speech, a digital glossary, scaffolded assistance, automated "coaches," and stories. Preliminary data are reported showing the frequency of use of some of these features as well as teachers' and students' opinions about them.

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Introduction

As the population of students in the United States becomes more diverse and national laws, including the No Child Left Behind Act, require schools to disaggregate student performance by subgroup, teachers are challenged to teach *all* students in their science classrooms to high standards. Many classes include students who are struggling with learning disabilities, such as dyslexia, or who have English language barriers, emotional or behavioral problems, lack of interest or engagement, or sensory and physical disabilities. To help teachers reach all of these students, materials are needed that provide multiple representations, support multiple means of expression and engagement, and provide a variety of assessment strategies.

The idea of Universal Design for Learning (UDL) is to provide materials with this expanded range of flexibility. Materials that are designed for flexibility from the ground up are likely to help *every* student. The increasing availability of computers and related digital devices are making greater flexibility available to more teachers and students on a routine basis.

There are, however, few classroom-ready science curriculum materials that make full use of the principles of UDL. While it is true that all good science curricula include as part of the fundamental pedagogy multiple representations of data (e.g., displaying a graph, the data, and text describing the information), this is only a start in meeting the full potential of UDL for making science education more effective for more students.

New UDL Science Curriculum Units

The Universal Design in Science Education project, funded by the National Science Foundation (ESI-0628242), is developing software so that elementary teachers can better meet each student's needs. The Concord Consortium has developed four two-week science curriculum units at each of two grade levels: grades 3-4 and 5-6. Students are engaged through driving questions:

- Why are there clouds?
- What do plants eat?
- What if there was no friction?
- What is electricity?

Probes are used for lab investigations and computer-based models are used for experimentation in virtual environments. Variable scaffolding for students is provided for both kinds of inquiry. The software can express information and mathematical relationships using text and vocalization as well as various representational formats.

This project is following the lead set by the Center for Applied Special Technology (CAST) with its work in the language arts area.[1] CAST developed and studied two reading tools that are now commercially available: Wiggleworks[2] and Thinking Reader[3].

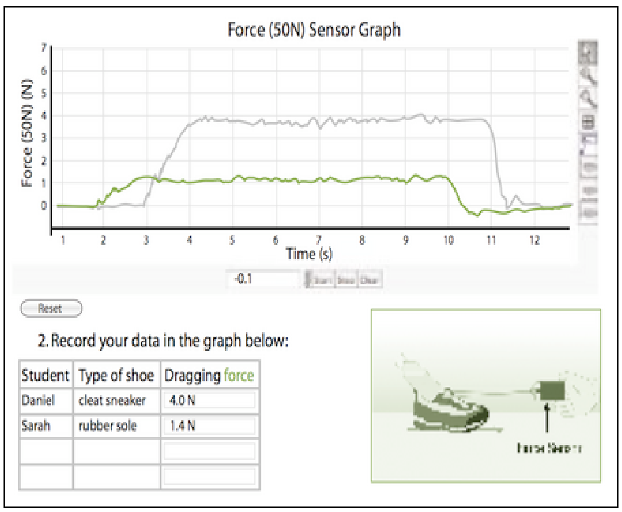

Figure 1: Students use a force sensor to measure the friction of different shoes in the UDL unit about friction.

With UDL software (when fully developed), teachers and students can select ways to approach a topic; choose how that topic will be presented (for instance, in English or Spanish, in a larger or smaller font size, with different background colors, or to be read aloud); and decide how best to demonstrate what the student has learned.

Figure 1 illustrates an activity from a unit in which students measure friction as different shoes are dragged across a surface. Units are designed to take two or more weeks and include many activities.

UDL Features of the New Software

As part of the project, our staff has developed a variety of features that make the curriculum accessible to larger numbers of students.

Smart graphs and models

The innovations developed for this project include “Smart Graphs” and “Smart Models” that each provides meta-analysis (Hazzard, 2009). That is, a graph is able to describe itself in words while highlighting a feature being described, for instance, the maximum, minimum, slope, time between two measurements, or difference of two measurements.

[1] See www.cast.org.
[2] http://teacher.scholastic.com/products/wiggleworks/index.htm
[3] http://www.tomsnyder.com/products/product.asp?sku=THITHI

Students can click on the part of a graph representing a certain event (e.g., the runner stopped for a while to rest) and the Smart Graph can provide supports and scaffolds to help students understand the graph. A molecular dynamics model can communicate important features of the display, including number and kind of atoms and molecules, average potential and kinetic energy, or the states of matter—liquid, solid, and gas—that are present.

Text-to-speech and a glossary

The specialized vocabulary used in science is a barrier for many students, especially those who are learning the English language or who have learning disabilities. As a result, we included features to make text more accessible to students. When students highlight text on the screen (by dragging a mouse over the text), the software reads the text aloud. In addition, words shown on the screen in blue are part of a glossary included in the software. When students click on one of these words they are first prompted to provide a definition of their own; then, the software displays the definition supplied by the authors. Students can also click on a glossary icon that results in a display of the entire set of glossary words for that unit.

Scaffolded assistance

With a science curriculum, the ultimate goal is student learning (in both content and the inquiry process itself), and learning must be measured. Students need multiple ways to demonstrate what they have learned. Using the UDL software, some learners may draw their responses, while others write. In addition, scaffolds are available that support students as they work on questions—ranging from a quick reminder to use pertinent information from the unit to a model response.

Stories

Each of the units begins with a fictional story. The stories are intended to engage students while introducing the driving question for the unit. Content-related science information is also included in the stories. The stories provide another cognitive channel for reaching students and may also serve to encourage teachers to integrate reading and science instruction, which is important in districts where reading dominates the time allocated for instruction of all kinds. For some stories, we are experimenting with making narrated versions available as well as print versions.

Coaches

CAST has done significant work studying brain networks and has identified three primary networks and how they function in learning, which they have applied to reading comprehension (Rose & Meyer, 2000; Rose & Meyer, 2002). Science coaches—animated on-screen robots that address the student with prompts, hints, and models—are aligned with the affective, strategic, and recognition networks and help students using the UDL units by sparking ideas and questions around the science content. The affective coach seeks to engage and motivate students by linking scientific knowledge and exploration to their real-world experiences and goals. The strategic coach helps students focus on what they need to know and how they can go about finding that out. The recognition coach guides students in gathering facts through exploration, observation, and experimentation and helps them both to display and interpret their results.

Science and equity

With Universal Design for Learning incorporated into the science curriculum, elementary students have access to instructional materials in a wide variety of forms to best meet their personal learning needs. Digital delivery makes the most of the computer's ability to personalize information while simultaneously taking advantage of the computational power of models, simulations, and real-time data analysis.

Prior research

This UDL project builds on several long lines of research in science education. These strands include research about using probes, models, and other technologies in teaching (e.g., Bayrakter, 2001; Linn, 2003; Linn et al., 2006; Tinker & Krajcik, 2001; Zucker et al., 2008); about cognitive factors affecting students' comprehension (e.g., Baddeley, 1986; Paivio, 1986); and about features of Universal Design for Learning (e.g., Freed, Rothberg, & Wlodkowski, 2003; Rose & Meyer, 2002).

One perspective on the convergence of evidence about the importance of using digital technology to improve science education is summarized in a research synthesis for policymakers recently published by the American Educational Research Association (AERA) that recommends schools ought to be using "today's powerful technologies to support visualization of scientific phenomena" (AERA, 2007).

Research Questions

The primary research question addressed in our work to date is: To what extent are the UDL features and approach developed as part of this project useful to students and teachers? More detailed questions include: Which features are used, how often, and by which students? What are teachers' and students' opinions about the UDL features?

A secondary set of research questions involves students' learning of science content, such as: How much have students learned in each unit? How does learning by students with special needs compare to learning by other students? Findings about these secondary research questions will be reported at a later date.

Methodology

Developmental trials were conducted in two schools, one in the northeast and one in the central part of the country. Later, additional trials were conducted with 15 teachers in two large urban school districts during the spring of 2008 (one district with about 50,000 students and the other with about 73,000 students) and during 2008-2009. This paper is based on data collected from those 15 teachers and the hundreds of students taught by the teachers in the first semester of the 2008-2009 school year.

The 15 teachers used four different units during the semester. The unit used most often was Intermediate Clouds; 11 classes used that unit. These 11 classes were taught by five teachers and included 316 students in grades 5 and 6. According to the teachers, the classes spent an average of about 4 weeks working on this unit. The data below pertain to these teachers and students. (Additional research is still taking place and further trials will be conducted during the 2009-2010 school year.)

The data collected to date include content-related pre- and post-tests that are part of each unit, background information provided by teachers about students' learning needs (e.g., whether English is their first language, whether they have an IEP), and log data from computer servers about uses of different features of the software. Students' responses to all questions embedded in the software units—including their drawings, graphs produced using probes, answers to constructed and multiple-choice items—are saved on a computer server. Additional data sources include surveys of teachers about features of the software and survey questions to students about their use of these science units. Teacher surveys were delivered using SurveyMonkey (www.surveymonkey.com/). Our UDL science software collects students' responses to survey questions (integrated into the units), along with their answers to science-related items.

Data are not being collected from a control group. One of the reasons is that the materials are expensive to produce and were not designed to have all the UDL features "turned off." As a result, it would be necessary to adapt or create a second set of comparable materials to be used in the control classes. Also, because students who are identified with special needs are in the minority, large numbers of classes would be needed for both experimental and control groups in order to compare statistically significant data from special needs students in each group.

Findings about the Primary Research Question

We collected data about the *uses* of the UDL software features and about teachers' and students' *opinions* about these features. The data sets will be enlarged as we continue to collect data over the next 12 to 18 months.

Usage of the UDL Features

The logging features of the software we developed allowed the project to collect information about students' use of a number of the UDL features, including text-to-speech and the glossary. These data are reported below.

The Glossary

Nearly 70% of the students clicked on one or more glossary words. The median number of words for which students sought definitions was 3. The average, 25, was much higher, reflecting the fact that 46 students used the glossary 50 or more times while using the Intermediate Clouds unit.

Words for which the students most often viewed glossary definitions included: cloud, condensation, cycle, energy, evaporation, fog, gas, heat, liquid, matter, molecule, and water vapor.

Text-to-speech

Every one of the 316 students used the text-to-speech feature at least once while they were engaged with the Intermediate Clouds unit. The median number of times students used text-to-speech was 12, and the average was more than 32.

Opinions about the Value of the UDL Features

The Glossary

As part of the post-test (which not all students completed), students were asked, "Was it helpful to have definitions of words (a glossary) in this unit?" The 218 responses were as follows:

Very helpful	44.0%
Somewhat helpful	48.2%
Not helpful	7.8%
Total	100.0%

A majority of the teachers were also enthusiastic about the glossary. They responded as follows:

Very useful	3
Useful	0
Not useful	2
Distracting or harmful	0
Total	5

Text-to-speech

As part of the post-test, students were asked, "Was it helpful to be able to highlight text and have the computer read it out loud?" The 215 student responses were as follows:

Very helpful	31.6%
Somewhat helpful	42.3%
Not helpful	26.0%
Total	100.0%

Teachers' opinions about the value of text-to-speech were more divided. The five teachers who used Intermediate Clouds were asked how useful they found a variety of software features. With respect to text-to-speech, the five answered as follows:

Very useful	1
Useful	1
Not useful	1
Distracting or harmful	2
Total	5

Other Features of the Software

The teachers who used Intermediate Clouds were asked how useful each of a variety of software features were. They responded as follows:

Especially considering the students in this class who often need extra help (e.g., reading or understanding written text; processing information; learning science), how useful are each of these features of the software in this unit?							
Answer Options	**Very useful (1)**	**Useful (2)**	**Not useful (3)**	**Distracting or harmful (4)**	**Don't know (5)**	**Rating Average**	**Response Count**
Glossary	3	0	2	0	0	1.80	5
Smart graphs	1	2	0	1	0	2.25	4
Models	1	3	0	1	0	2.20	5
Narrated stories	1	1	2	1	0	2.60	5
Text-to-speech	1	1	1	2	0	2.80	5
Leveled questions	2	2	0	0	1	2.20	5
Coaches (robots)	0	2	2	0	1	3.00	5
Drawing tools (if any)	1	3	0	1	0	2.20	5
Translation (Spanish)	0	1	1	0	2	3.75	4
Adjustable text size	0	2	1	1	1	3.20	5
Lab book	0	4	0	0	1	2.60	5

Discussion

The Universal Design in Science Education project poses many challenges. First, the technology infrastructure in many school systems is less capable than one would wish. As a result, a substantial amount of effort has been needed to solve technical problems in the schools that are testing the software. Second, most teachers are unfamiliar with the digital medium as a way of delivering weeks-long units of instruction, so there is much for them to learn in order to manage instruction well. We find that the use of UDL features varies greatly from one classroom to another, based in part on teachers' preferences.

Despite these challenges, many students use UDL features and believe they are helpful. Almost everyone who uses a computer has enlarged a page or a font to make it more legible. In time, the use of glossaries, text-to-speech, and other UDL features will also become routine, we believe. The challenge is to integrate UDL features thoughtfully and make sure they support effective science instruction, especially for students who need extra help. The Smart Graph has emerged as a particularly promising UDL feature. We have applied for additional funds to conduct experimental research studies about Smart Graphs, which we believe have significant potential to improve teaching and learning in both science and mathematics. Future research is planned that will provide more information about the use and impacts of Smart Graphs.

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